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## Coal in the 21st Century: a climate of change and uncertainty

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# Coal in the twenty-first century: a climate of change and uncertainty

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Coal presents a particular set of challenges when balancing energy policy goals. Despite presenting viable solutions to the problems of energy security and global energy poverty, coal struggles, given its greenhouse-gas drawbacks, in a world of increasingly harmful climate change. Notwithstanding the harm caused to the environment, coal remains an expanding low-price route to meeting local energy needs. It is forecasted to remain a major global resource for the foreseeable future. In the short term it is predicted to have a 26% share of the global energy mix. Recent years have witnessed severe deviations from previously stable trends in coal markets and policy dynamics. According to the predictions by the International Energy Agency, a variety of factors ranging from the planned phase-out of coal in countries such as Denmark, France and the UK, to changes in policy in China and import-dependency in India, and demand drop in the US have together resulted in the largest decline in coal production since 1971 in 2015. This paper seeks to outline basic coal facts, recent market trends and directions globally and provides an overview of issues shaping the future of coal in the twenty-first century.

## 1. Introduction

Coal has been one of the most important sources of primary energy, together with oil and natural gas, for many decades now. In 2016, despite falling demand, coal accounted for 26% of the global energy mix, at a total of 5357 Mtce (1 Mt of coal equivalent = 0.67 Mt of oil equivalent = 7.778 TWh) (IEA, 2017a). While demand for coal, according to the International Energy Agency (IEA) projections, is forecast to undergo a slow and structural decline in Europe, Canada, the US and China, it is predicted to grow in India, south-east Asia and some other Asian countries (IEA, 2017a).

Despite complex trends in both supply and demand, it can be stated with some confidence that coal will continue to be a significant part of the global energy mix in the mid-to-long term. To be able to analyse fully the future of coal, it is paramount to understand factors over the past many decades that have contributed to the current status and position of coal in the energy mix.

Evidence of coal burning can be traced to the Bronze Age in Britain (Everett *et al.*, 2012). Historically, coal was primarily used to replace burning wood for heating, cooking, lighting and for industrial production. In the 1600s, coke replaced charcoal for smelting iron, which was later used to produce large cast-iron cylinders for steam engines. Coal made a noteworthy contribution to Britain's performance as an industrial nation throughout the eighteenth, nineteenth and twentieth centuries

by fuelling industrial machinery and almost all modes of transportation (Supple, 1989: p. 5).

The development of the steam engine on the back of James Watt's condenser invention in the 1780s, the steam turbine and the later electric generator in the nineteenth century drove economic growth increasing coal output across all industrialised nations. In Britain, coal production grew at 3.5% a year, from 10 Mt in 1800 to over 80 Mt in 1861. The world production of coal in 1900 was estimated at 800 Mt and growing at about 5% annually (Everett *et al.*, 2012: pp. 145–146). Over many decades, coal has retained its position of prominence in the energy mix owing not just to its relative ease of extraction and global abundance, but also its wide range of types and associated uses.

In more recent times, resulting from a combination of factors, the otherwise stable growth trajectory of coal has witnessed serious fluctuations. These changes, resulting from shifts in global demand centres and trade flows, have, in effect, triggered significant shifts in energy geopolitics. Concerns over changing climate and seriously deteriorating air quality in many cities of the world, coupled with a rather slow transition to clean energy pathways have challenged the viability and place of coal in the future energy mix. In addition, because of its cost competitiveness, affordability and wide availability, coal emerges more prominent than ever in ensuring security of supply for fast-growing developing economies.

This paper provides an overview of coal facts, characteristic features and principles that have guided the emergence of coal over the centuries as a primary energy source. It also outlines the recent developments in market structure and policy paradigm that are likely to impact the place of coal in the future global energy mix. These fundamental realities are important considerations for designing future energy systems that can meet the wider energy policy objectives fairly and equitably for all the nations of the world. The sections that follow span consideration of the formation of coal through to its classification, uses and current reserves. The paper outlines in some detail changes in coal demand, trading mechanisms and emerging coal futures and it concludes with a projected outlook into the future.

## 2. Coal facts

### 2.1 Classification of coal

Coal was generated in the Carboniferous Period starting around 360 million to 290 million years ago through the build-up of silt and other sediments (WCA, 2017). Tectonic movements in the earth's crust buried the carbon matter of swamps and peat bogs to great depths, exposing the materials to a change in temperature and pressure, and converting them through the process known as coalification to various kinds of coals (Gross and O'Kane, 1994; Kendall *et al.*, 2010).

The key characteristics of coal are calorific value, moisture content, residual ash, volatility and sulfur content (which can vary greatly, depending on the area where it is mined). Coal can be classified based on its rank and its constituent microscopic organic constituents, also known as macerals. Macerals are optically homogenous aggregates of organic substances possessing distinct chemical and physical properties, which give coal its distinct properties (Scott, 2002; Spackman, 1958).

The classification of coal is important as it determines its best use. The British Geological Survey classifies coal as humic (composed of woody remains of plant debris) or sapropelic (containing wax-rich remains of plant spores and algae). Humic coal is further sub-classified as vitrain, clarain, durain and fusain; and sapropelic coal as cannel coal and bog head coal (Kendall *et al.*, 2010). Based on macerals, coal can be divided into the lithological types classified as vitrinite, exinite and inertinite.

The structure of coal consists of rings of six carbon atoms in layered arrangement with hydrogen, oxygen, traces of organic components like sulfur and nitrogen, together with some moisture and other inert mineral materials (for details on coal classification, see the articles by Chaudhuri (2016) and Scott (2002)). A full chemical analysis of coal to list the main constituents by mass can be done by a process called an

ultimate analysis. The percentage of fixed carbon in coal is determined by a process called proximate analysis (for details see the book edited by Karr (2013)).

The rank of coal is the measure of the degree of metamorphism, or coalification, undergone by it, which in turn also indicates the amount of moisture and carbon present. Based on its rank, for example, coal can be classified as hard (or black) coal or brown coal. Hard coal types like bituminous and anthracite rank higher than lignite and sub-bituminous coal. Lignite or brown coal is also often used for electricity production but its calorific value is usually much lower than that of thermal coal. Lignite is usually produced and used domestically and any international trade is negligible. This is a consequence of the unattractive ratio of transport costs to commodity value. The heat value of different types of coal is determined by its composition. The percentage of fixed carbon, hydrogen and oxygen can be analysed by proximate analysis of coal. As the rank of coal increases, so does its heat of combustion. Figure 1 lists the classification of coal according to its rank, and various uses against each coal type.

### 2.2 Uses of coal

Coal has been used to generate electricity, for key industrial processes such as steel production and cement manufacturing and as a precursor to liquid fuels. The type of coal used for electricity generation is usually referred to as steam or thermal coal, while coal used for steel manufacturing is metallurgical coal or coking coal. The main difference between the two is in their end use based on properties such as carbon content and calorific value, with the typical calorific value of steam coal at 6000 kcal/kg (these can vary based on the geographical region). A number of by-products, commonly known as coal-combustion products (CCPs) are also produced by burning coal in coal-fired power plants; these can have important industrial uses.

Steam or thermal coal is used to generate electricity in coal-fired power plants, where powdered, or pulverised, coal is blown into combustion chambers of the boilers and burnt at high temperatures. The water is converted into steam in tubes lining the boiler. The high-pressure steam rotates the blades of the turbine shaft at high speed and generates electricity. The steam passes through the turbine and returns back to the boiler in condensed form to undergo subsequent cycles, as shown in Figure 2. Currently, around 40% of global electricity is generated by coal (WCA, 2017).

As the industry is currently configured, coal is dominant in the manufacture of iron and steel. Steel is the very backbone of heavy industry activities (e.g. shipping, aviation, building, utilities, equipment etc.). Around 64% of steel produced globally uses iron made from blast furnaces that are coal-fired. Iron

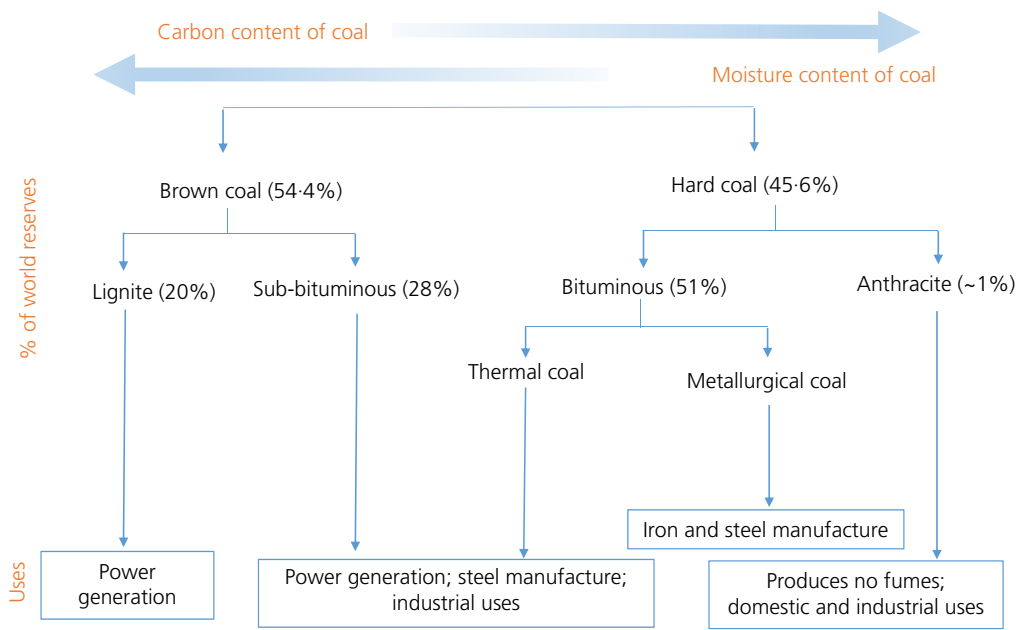


Figure 1. Classification of coal based on its rank (source: adapted from WCA (2017), WEC (2018))

ore, coking coal and limestone (used as flux to collect impurities) serve as raw materials, which are fed from the top of the blast furnace, while hot air (around 1200°C) is blown into the lower sections.

The hot air burns the coke to produce carbon monoxide, which removes the oxygen and reduces the iron ore to molten iron,

which is drained off the furnace through taps at the bottom of the furnace. The molten iron thus produced is treated with additional limestone and 99% pure oxygen at basic oxygen furnaces (BOFs), which increase the temperature up to 1700°C. In the BOF, small amounts of steel scrap (<30%) are mixed with the iron and flux. The scrap melts at these high temperatures, oxidises the impurities, and reduces the carbon content by

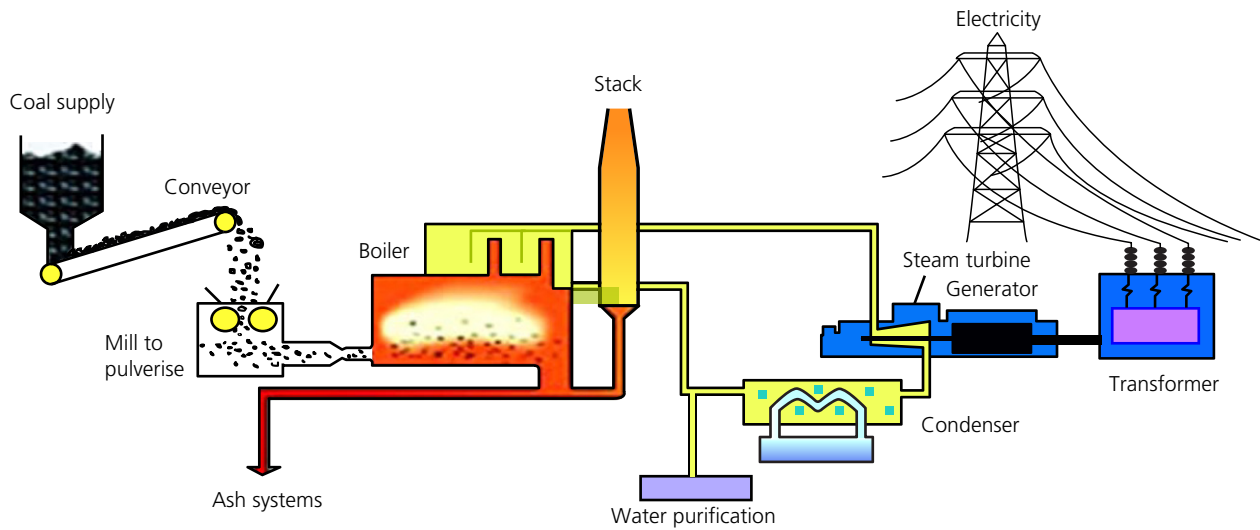


Figure 2. Electricity generation using coal (source: adapted from WCA (2019))

90%. The process results in the production of liquid steel as shown in Figure 3.

Around 64% of world steel today is produced at BOFs, while 33% is produced at electric arc furnaces (ERFs). At ERFs, electrodes are subjected to power to produce an arc of electricity, which in turn raises the temperature to 1600°C to produce molten steel. Pulverised-coal injection (PCI) technology allows a wide variety of coal, including relatively cheaper steam coal, to be injected directly into the blast furnace and is increasingly being used, as reported by the World Coal Association (WCA, 2017).

Coal is also used as a liquid fuel, which can be further refined through a process called liquefaction to produce transport fuels and other oil-generated products like plastics and solvents. There are two different approaches to liquefaction: direct and indirect liquefaction. Direct coal liquefaction (DCL) technology involves converting coal to partially refined synthetic crude oil, which can be further refined to produce synthetic gasoline, diesel and other hydrocarbon products similar to those derived from crude oil. In indirect coal liquefaction (ICL) coal is gasified to make synthesis gas or 'syngas', which can be then used to produce synthetic oil products

(Williams and Larson, 2003: pp. 103–104). (Further details on liquefaction can be found in the paper by Williams and Larson (2003).)

By acting as a substitute for crude oil in a world scrambling for secure supplies of energy, coal further increases its presence in the energy mix. Based on the Fischer–Tropsch process, the largest coal-to-liquid (CTL) production capacity is currently located in South Africa (EIA, 2010). This coal-based commercial liquefaction process has been estimated to meet one-third of the current domestic liquid fuel requirement in South Africa (WCI, 2005). Figure 4 shows some of the liquid fuel products produced by coal gasification (WCI, 2007a).

Coal is also used as an energy source to produce cement. High-temperature kilns burn coal in powdered form, which raises the temperature to 1450°C, altering the physical and chemical properties of calcium carbonate, silica, iron oxide and alumina and producing clinker, which is mixed with gypsum and finely ground to produce cement. Important CCPs include fly ash, bottom ash, boiler slag and flue gas desulfurisation gypsum, most of which can be recycled and used as important replacements for primary raw materials (WCI, 2005).

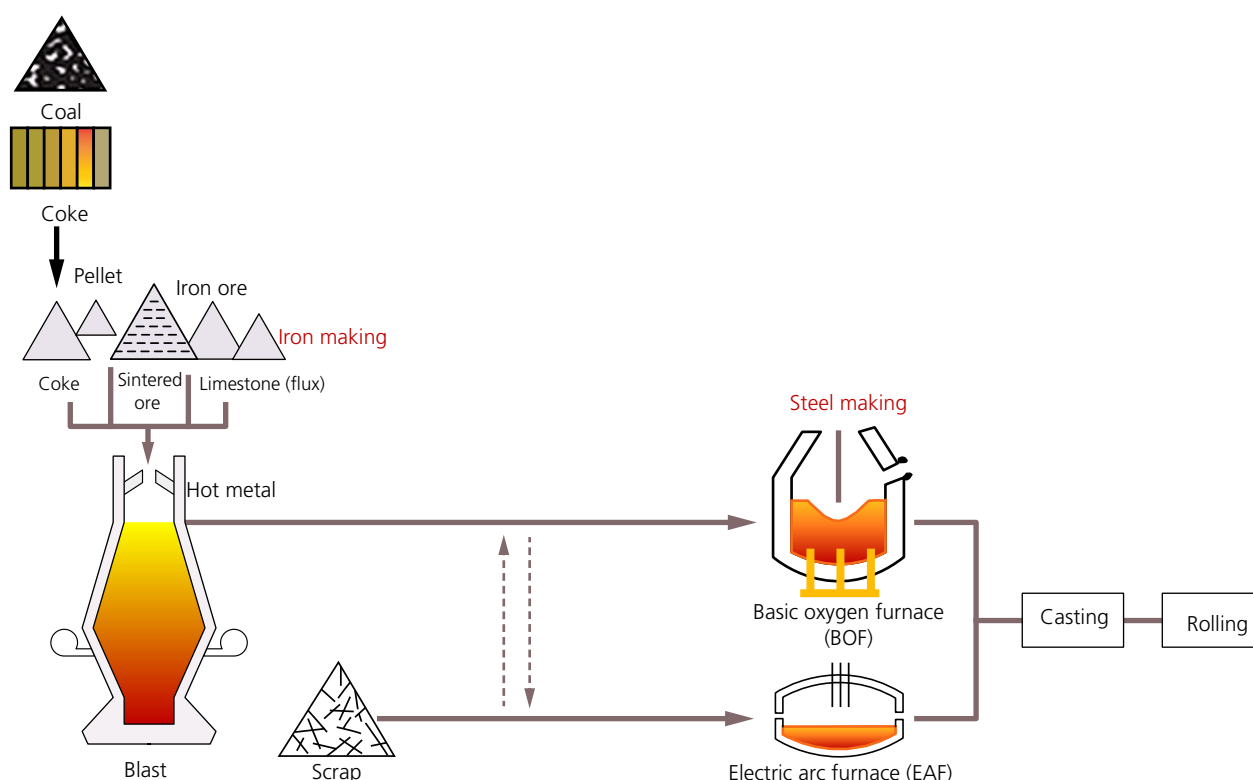
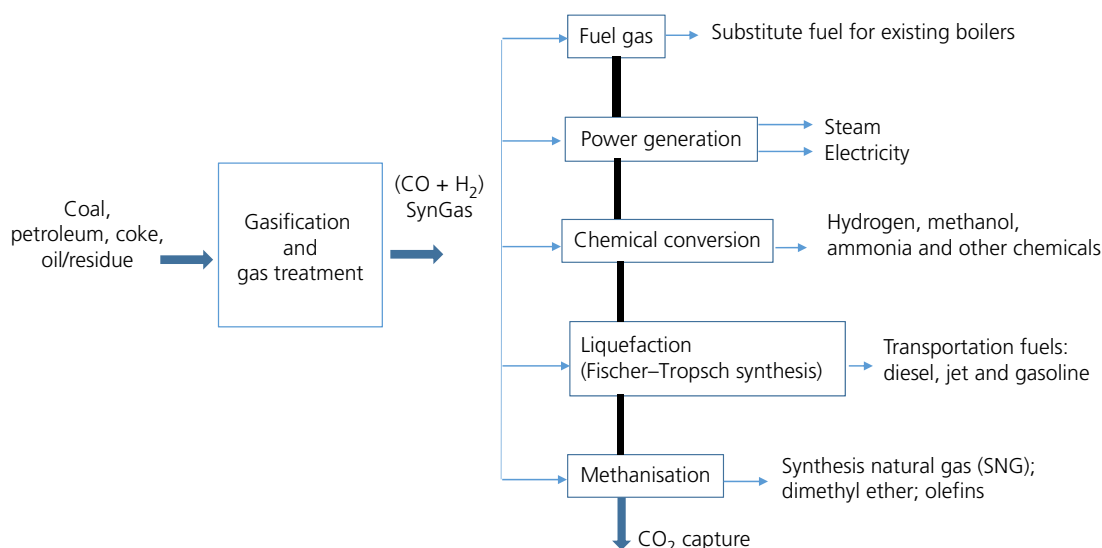


Figure 3. Steel production from coal (source: adapted from WCA (2016))



**Figure 4.** Coal liquid fuel products (source: inspired by WCI (2006)). CO, carbon monoxide; CO<sub>2</sub>, carbon dioxide; H, hydrogen

### 2.2.1 Coal to gas

In around 1800, coal was burned in the absence of air, producing an illuminating gas, which was used for commercial gas lighting. This contained sulfur impurities of coal, present as hydrogen sulfide, and nitrogen in the form of ammonia. This noxious gas was later piped into homes and even used as a controllable fuel source for cooking. Most towns and cities in industrialised countries, by the end of the nineteenth century, had gasworks that produced ‘town gas’ and coke (Thomas, 2014).

The process of producing combustible town gas from coal was as follows: bituminous coal was loaded into closed retorts and heated at very high temperatures. The impure gas that was produced was then cleaned through a set of processes, which included bubbling it through water to dissolve the ammonia produced by nitrogen present in coal and dissolving the oil and tars as a liquid layer; passing the gas over iron oxide to remove hydrogen sulfide; and putting the gas through a final wash to remove any remaining impurities like benzene. The final cleaned gas contained carbon monoxide, methane, hydrogen and hydrocarbons like ethylene and acetylene. The bright illuminating colour of the gas came from its hydrocarbon components.

The residual material would be a batch of coke, which could be reused in coal furnaces or sold as a heating fuel. A range of other end products, with important applications, could also be recovered. The ammonia was sold as fertiliser, coal tar was distilled into a range of oils: light (boiling point (bp) <200°C), middle (bp 200–240°C), heavy (bp 240–270°C) or anthracene (bp 270–360°C), and the residual thick tar and pitch was even

used for making roads. Other ways to make gas from coal were also employed at this time, one of which was by spraying water on red-hot coke making what was known as ‘water gas’ (Everett *et al.*, 2012; Shadle *et al.*, 2000; Thomas, 2014).

The basic distillation process improved over time, producing more gas and making it cheaper. By the 1920s, town gas was sold in a similar manner to how natural gas is today: metred and based on heat content. Natural gas today has completely replaced town gas, because of its higher energy density, better cleanliness and greatly reduced toxicity. Nevertheless, one must acknowledge that town gas did greatly modernise heating, cooking and lighting in the nineteenth century.

## 3. International coal markets and international coal trade: a shift to the east

The last two decades have been remarkable for the coal sector. The global structure and trends of coal demand have gone through a series of significant changes primarily with the emergence of demand growth from economies in the east and growing concerns over environmental protection. Historically, coal markets have been highly localised and specific to specialised markets. The emergence of seaborne trade for coal has indeed unified these separate coal markets into a functional market that traded 1333.5 Mt of coal, representing 17.6% of coal consumption on an energy basis in 2016 (IEA, 2017a). The following sections highlight some of the defining features of coal markets and international trading of coal.

3.1 Global coal markets

Two different kinds of markets exist for internationally traded coal: the steam coal market for power generation, and the coking coal market for its use as a chemical reductant as well as an energy source. There are also maritime and inland markets for coal, but the inland trade is relatively negligible in comparison and only takes place between neighbouring countries. In this paper, as in most other publications, the focus remains on the maritime trade of coal, because of its wider policy and market implications. The maritime hard coal market can be further broken down into steam and coking coal markets.

It must also be stated that the markets for coking and steam coal are not always distinct, although the market for coking coal is more unified and unitary with a few suppliers serving the market (Ritschel and Schiffer, 2007). The seaborne thermal or steam coal market comprises two segments: the Atlantic Market (comprising North, Central and South America, Europe and the Mediterranean countries) and the Pacific Market (serving Asian consumers). Distances determine the mode of coal transportation, which is generally carried out over longer distances using ships, or using trucks, trains and barges over shorter distances and within domestic markets (WCI, 2005). Figure 5 showcases how coal is transported between various global markets.

A key factor that regulates the trade of coal is the level of freight rates, enabling Atlantic or Pacific producers to supply coal at competitive prices into distant markets (Ritschel and

Schiffer, 2007; WCA, 2017). The transportation cost therefore accounts for a large share of the total delivered price of coal, significantly impacting the demand and supply dynamics of seaborne coal. Freight rates can be volatile and change very rapidly based on market conditions, reflecting broader macro-economic drivers and conditions of other commodity markets (as goods like grain and iron ore are transported on the same vessels, together with coal).

Between 2003 and 2008, freight rates rose steadily due to a variety of factors such as the increase in the coal trade, the rising demand for dry-bulk carriers for transporting other commodities, the surging demand in China and strong grain exports. They reached an all-time high as commodity prices peaked in 2008 before declining by 94% as the world markets crashed. The leading index for dry-bulk carrier rates is the Baltic dry index (BDI), issued by the Baltic index (ECS, 2010). More recently, due to depressed demands of iron ore and coal and a glut of carriers, the BDI dropped to 290 points, its lowest on the Baltic Exchange, in February 2016. Fluctuating oil prices significantly impact bunker fuel costs, and in turn add volatility to the freight costs.

3.1.1 Baltic dry index

The BDI, compiled and posted by the Baltic Exchange of London, is the measure of price of moving raw materials by sea, and covers four types of bulk cargo ships on 23 routes. With over 600 members, the exchange is the world's leading source of independent maritime information for the

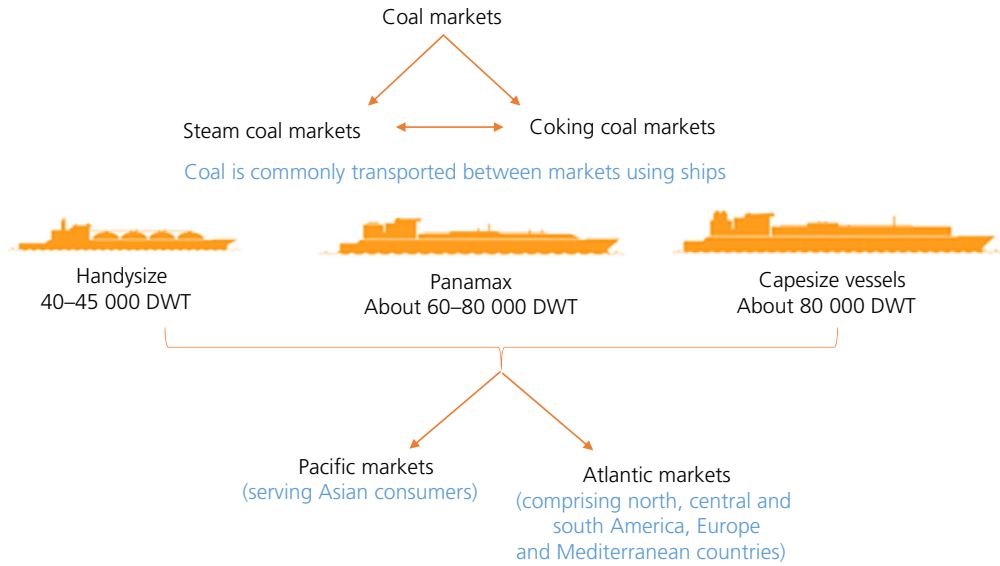


Figure 5. Coal transportation between markets (source: adapted from WCA (2017)). DWT, dead weight tonnes



trading of shipping contracts (physical as well as derivative) (BE, 2017).

BDI is a measure of the rather inflexible supply of dry bulk through a fleet of 9000 vessels worldwide versus the demand for shipping capacity. It measures the global supply and demand for metallic ores, grains, coal, steel and other industrial minerals. Iron ore dominates the index followed by coal (coking as well as thermal), copper, bauxite, steel, timber and cement. By measuring the transportation cost of raw materials used for production of finished industry goods, BDI helps to predict short-term economic activity and is therefore an important economic indicator. Because the global and regional demand for dry bulk fluctuates sharply, the index has exhibited extreme volatilities in recent years. Movements in shipping costs between 2003 and 2017 are shown in Figure 6.

### 3.2 International coal trade

Through the various modes of transportation (Figure 5), coal is traded all over the world. It is produced in over 50 countries and consumed in more than 70 countries. Efficient means of transportation and a large number of suppliers of coal ensures an effective global trade of coal through the formation of an emerging competitive market. According to IEA statistics, around 1333.5 Mt of coal was traded internationally in 2016. Table 1 presents the data on global coal trade in 2016 as reported by the IEA (2017). Steam coal exports increased by 14.6 Mt (1.5%) and coking coal exports by 10.2 Mt (3.4%). The total exports have increased by 21.7% between 2010 and 2016 and doubled (105.3%) since 2000. These figures portray well the dynamics of the global coal trade. Almost 92% of traded volume is seaborne, while the remainder is cross-border overland trade.

Australia and Indonesia remained the largest coal exporters in 2016 accounting for 29.2 and 27.7% of the total quantity exported, while the Russian Federation contributed a 12.8% share of the total. The ten largest exporting countries also included Colombia (6.2%), South Africa (5.7%), USA (4.1%), Netherlands (3%), Canada (2.2%), Mongolia (1.9%) and Kazakhstan (1.9%). Together these ten countries shipped 95% of global coal exports. A total of 1331.3 Mt of coal was imported in 2016, according to IEA reports, of which the People's Republic of China imported 19.2% and India 15%. Other top importers included Japan, Korea, Chinese Taipei, the Netherlands, Germany, Turkey, Malaysia and the Russian Federation. A global overview of coal trade that took place between various markets in 2014 is showcased in Figure 7. It is not surprising that the biggest importers are China and India, the countries with the largest populations in the world. They are also two of the fastest growing large economies under huge economic and political pressure to make electricity available to their expanding population and industrial bases.

A number of factors contribute to the changing dynamics and rapid development in the global coal trade. All key forecasts assume ongoing growth in coal consumption and world trade backed by a strong growth and changing policy dynamics in developing countries such as India, China and south-east Asian countries. While there is strong growth in the Asian region, a steady decline is predicted in European production and consumption. Another important factor is the relative cost competitiveness of world, or traded, coal over domestic coal and the ease with which coal can be shipped across markets with falling freight rates. This has significantly changed the global trade dynamics of coal. Additionally, the emergence of

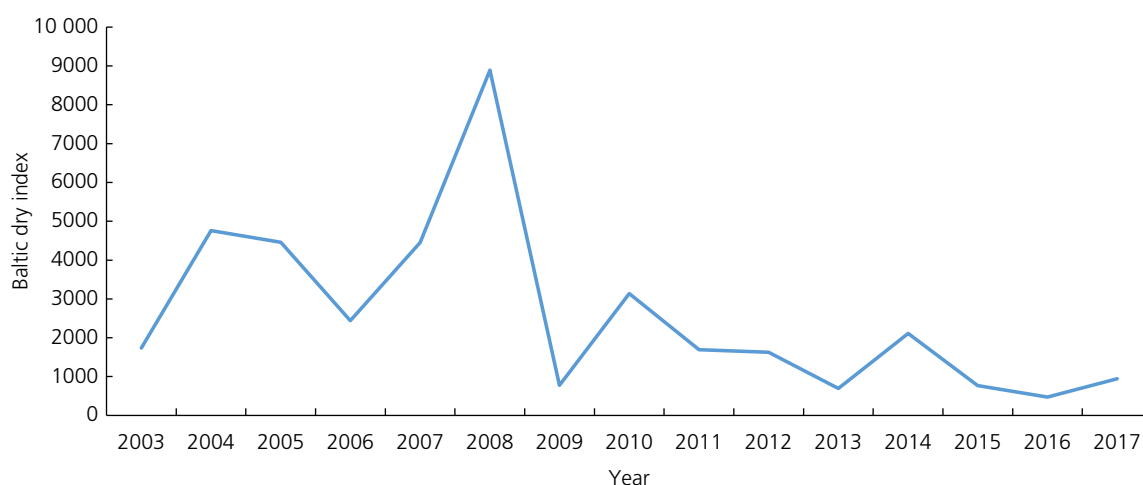


Figure 6. Shipping costs – BDI (2003–present) (source: BDI (2017), also BE (2017))



Table 1. World coal trade in 2016

Coal trade	Amount of coal traded: Mt
Steam coal exports	1010.4
Coking coal exports	314.1
Lignite exports	9.0
Steam coal imports	1045.0
Coking coal imports	282.1
Lignite imports	402
Total exports	1333.5
Total imports	1331.3
Balancing item <sup>a</sup>	-2.2

Source: IEA (2017)

<sup>a</sup>Balancing item is the difference between total coal imports and exports, and takes into account coal in-transit, unaccounted-for coal, and various reporting discrepancies followed by importing and exporting countries

new swing suppliers has also significantly impacted the coal trade dynamics.

Historically, geography has been a major component shaping coal trade markets with set boundaries and well-established suppliers within each market. The USA and subsequently South Africa were the major established marginal or 'swing' suppliers of coal to both the Atlantic and Pacific markets

(Cameron, 1997). In his pioneering work, *The World Price of Coal*, Ellerman based his findings on the principle that 'US is the residual supplier of coal, determining the upper limit to prices in the world coal market' (Ellerman, 1995: p. 499; also Cameron, 1997: p. 24). In the 1980s, the USA had a large domestic market and substantial railroad and port capacity to bolster its place as the residual supplier (Light *et al.*, 1999).

South Africa's pattern of export, on the contrary, changed as a response to economic sanctions imposed on it from July 1986 to 1992/1993. Its exports to Asia during this period more than doubled, but subsequently declined (Cameron, 1997). The global trade landscape of the 2000s is very different from what it was in the late 1980s and 1990s. Many swing suppliers – that is, those that supply coal depending on attractive price and market situations – are now routinely trading into both markets, backed by massive reductions in freight costs in recent years. Figure 8 highlights the coal movements in 2015.

### 3.3 International coal pricing

Coal markets are rapidly evolving into commodity trading markets and transactions based on coal indices are becoming established. Not long ago the spot markets for coal were not clearly defined (Cameron, 1997). However, with the emergence

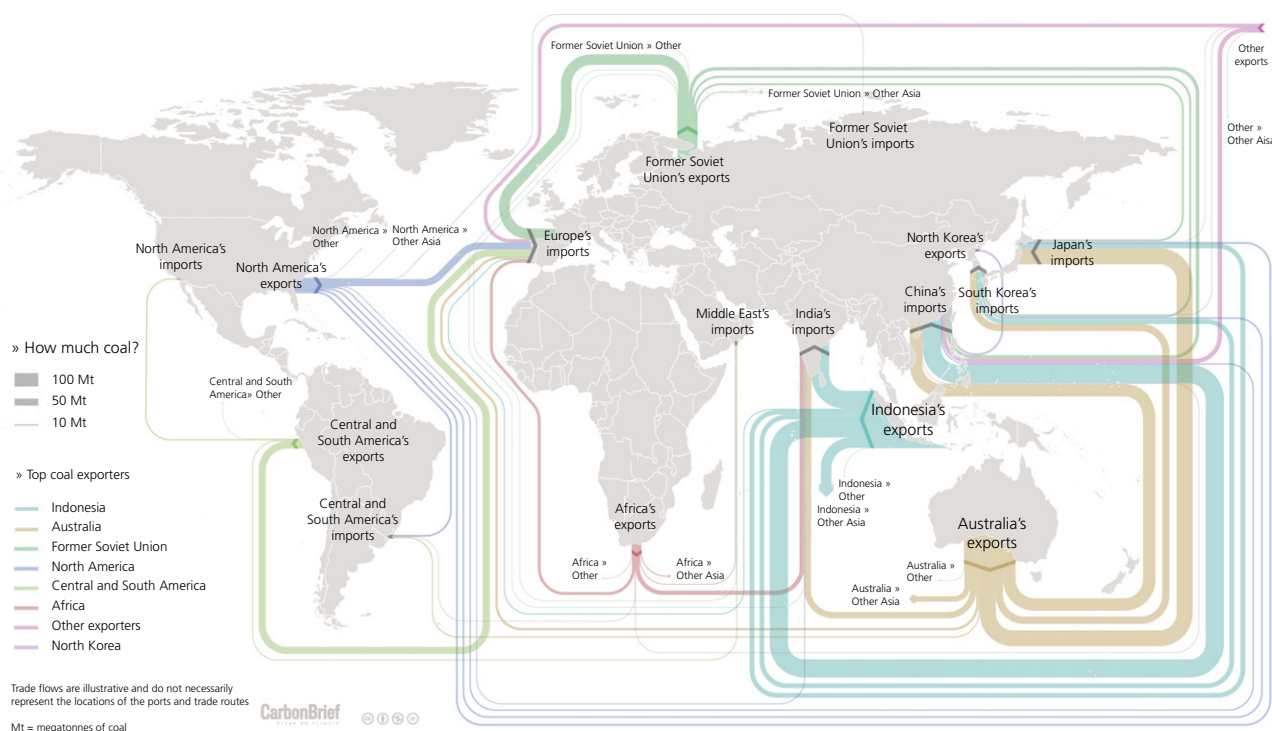
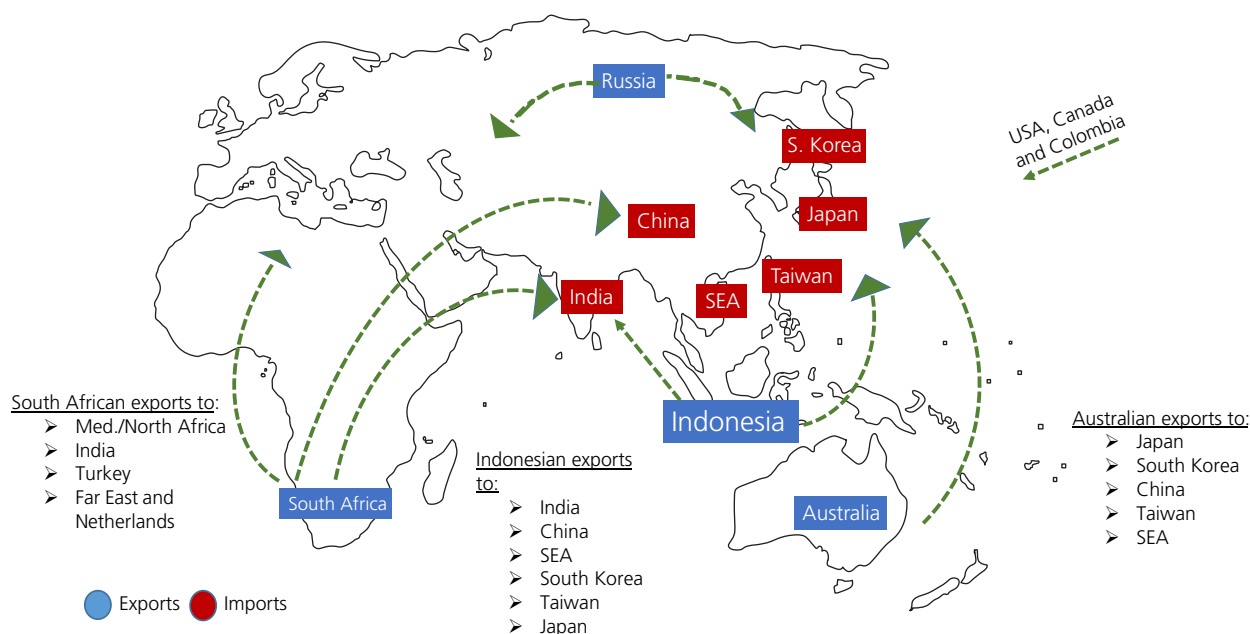


Figure 7. Global coal trade map 2014 (source: downloaded from Carbonbrief (2016), used with authors' permission). A full-colour version of this figure can be found on the ICE Virtual Library ([www.icevirtuallibrary.com](http://www.icevirtuallibrary.com))



**Figure 8.** Coal movements in the Pacific market in 2015 in Mt (source: inspired by WCT (2018); Schernikau (2017)). SEA, south-east Asia

of coal futures and derivatives, and the establishment of global coal exchanges, the market structure for coal has changed significantly (ECS, 2007).

### 3.3.1 Recent price developments

The prices of internationally traded coal are commonly expressed in US dollars per ton or ton of coal equivalent (tce). As shown in Figure 8, coal exports use ‘free on board’ (FOB) prices – the price of coal and the cost incurred to transport coal from the mine to a terminal in the country exporting it. Imports use ‘cost, insurance and freight’ (CIF) prices – the FOB price plus the cost to transport coal to the receiving port in the importing country. ‘Free at shipside’ (FAS) price, which does not include the cost of loading, is used in the USA instead of the FOB price (ECS, 2007). Prices for coal vary according to its uses, attributes and markets. Historically, coking coal prices were higher than those for thermal or steam coal prices. Growing electricity needs for increasing populations in emerging economies, however, have rapidly expanded the international trade in thermal coal.

The cost of various constituent stages of the coal supply chain is crucial in determining its cost competitiveness over other sources of primary energy. For example, coal is less capital intensive than oil and gas, requiring comparatively less investment in developing new mining capacities and carrying significantly less investment risk than the latter. This becomes

evident in the order presented for each energy source based on the total investments needed during the entire supply chain (expressed in tce): coal – US\$3.4/tce; oil – US\$15.4/tce; gas – US\$19.6/tce, as identified by The World Energy Investment Outlook of the IEA (Ritschel and Schiffer, 2007). Other crucial components that determine the cost of coal are additional key representative costs in the value chain like free mine costs based on type of mining operation (whether it be opencast or underground mine), domestic transport cost, port handling cost, sea freight costs, labour and productivity cost and so on, as shown in Figure 9. These costs differ across a range of attributing factors which are specific to the countries where the coal comes from and sells into, explaining the large cost range of coal. Freight rates contribute significantly towards the final cost of traded coal and thus have a direct impact on its demand and trade flows.

The recent price competition in the world’s coal markets has been mostly governed by fluctuating supply and demand cycles, with shortages in supply following excessive supply resulting from steadily rising capacity utilisation of the mining capacities for exports. This triggered volatilities and price peaks. Competitive CIF prices make it profitable for suppliers to trade coal between markets. Depending on the price situation, coal varieties are interchangeably used with certain steam coals prepared and marketed as more volatile coking coals and vice versa.

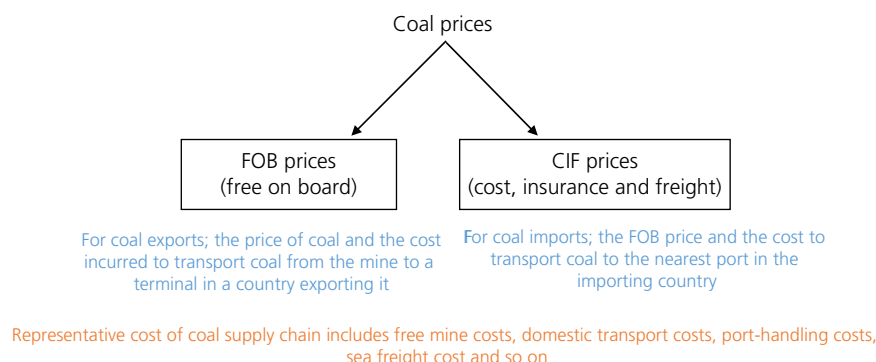


Figure 9. Development of coal prices (source: WCA, 2017)

### 3.3.2 Coal contracts

Long-term contracts are very widely used in the coal sector because of associated capital investments and characteristic quality-mediated usage, and are formed between coal buyers and sellers. These serve as an important indication into future developments, impacting decisions on long-term investments. The pricing system, under long-term contracts, has undergone systemic structural changes in the past decades. Traditionally, benchmark prices were based on FOB prices. However, in more recent times short-term and spot contracts exist alongside these long-term contracts (ECS, 2007). Some of the notable players in the international coal market are listed in Table 2.

### 3.3.3 Coal spot prices, futures and derivatives

Both long-term supply contracts and spot contracts exist between sellers and buyers in the world of hard coal markets. Spot contracts help the consumers establish closer alignments with the existing market situations, while long-term contracts

are mostly encountered in cases where enduring interdependencies exist between producers and consumers. Tender deals, or purchases, linked to bidding procedure are a common variant of spot purchases for deliveries involving larger volumes and covering longer timescales. Spot transactions have important features making them an important instrument in the coal price formation mechanism. Spot prices allow for mark-ups to be levied on long-term contract prices in tight market conditions, and for price reductions when market conditions become relaxed. Spot prices in buyers' markets therefore remain below longer-term contract prices. Spot prices also perform a marker function for contracts for future deliveries, thereby affecting their prices (Ritschel and Schiffer, 2007).

A number of well-established spot prices exist at different locations. Two important spot prices for coal exports are: FOB spot price at Richards Bay, South Africa and FOB spot price at Newcastle, Australia. The main import prices are CIF spot prices at Amsterdam-Rotterdam-Antwerp (ARA) in

Table 2. Global market players in coal trade

Electronic trading platforms	Banks	Physical coal trading companies	Utility traders of physical coal	Bank traders of physical coal
<ul style="list-style-type: none"> <li>GlobalCOAL</li> <li>Glencore</li> </ul>	<ul style="list-style-type: none"> <li>Morgan Stanley, Merrill Lynch</li> <li>Macquarie Bank</li> <li>RBS Semptra</li> <li>EDF Trading</li> <li>E.ON Trading</li> <li>RWE</li> </ul>	<ul style="list-style-type: none"> <li>Glencore</li> <li>Cargill</li> <li>Noble Group</li> <li>Vitol Group</li> <li>Trafigura</li> <li>Mercuria Energy Group Ltd</li> <li>Louis Dreyfus Highbridge Energy LLC</li> <li>Bulk Trading SA</li> <li>Flame SA</li> <li>Peabody Energy</li> </ul>	<ul style="list-style-type: none"> <li>Edf Trading</li> <li>Rwe Supply And Trading</li> <li>Nuon</li> <li>Essent</li> </ul>	<ul style="list-style-type: none"> <li>Macquarie Group</li> <li>RBS Semptra Energy</li> <li>Goldman Sachs</li> <li>Morgan Stanley</li> <li>Merrill Lynch</li> <li>Deutsche Bank</li> </ul>

Source: Reuters (2009)

north-west Europe and Japanese import CIF prices. A number of regional spot prices such as the ‘Central Appalachia’, ‘Northern Appalachia’, ‘Illinois Basin’, ‘Powder River Basin’ and ‘Uinta Basin’ exist in the USA. These spot prices are regularly published by reporting agencies – for example, Argus, McCloskey Coal Information Services (MCIS), Platts and South African Coal Report (SACR) (ECS, 2007).

Coal trading, with the development of electronic trading and financial derivatives, has undergone a step transition in the recent past and can be considered representative of future markets. Coal is now traded financially on paper or physically, by, and among, new participating players like banks and financial institutions, as well as existing ones like electricity utilities and mining companies, changing the traditional nature of coal trading and pricing. Coal futures markets are less mature than oil futures markets at this stage, as coal futures contracts still tend to be settled in cash against published indices, except at the New York Mercantile Exchange (Nymex) and the ASX (Australian Securities Exchange).

Before the onset of futures markets, over-the-counter (OTC) swap markets were the popular trading instrument. OTC trading took place outside the exchange in the form of a negotiation between two parties and thus differed from a futures or derivatives exchange – a financial institution overseeing a standardised exchange of contract between involved parties (ECS, 2007). A swap helps hedge against price risks by enabling the player to exchange the price of a chosen brand with a fixed price, or a benchmark-linked price, or that linked to a composite index for a specified amount of time by entering into an arrangement with a financial institution. The terms of an OTC derivative can be customised to suit the parties involved in the negotiation, and can be very opaque by virtue of these being less regulated.

All Publications Index number 2 (API2), a price index of CIF steam coal delivered to the ARA area in north-west Europe, is the largest coal derivatives market, followed by API4, a price index of FOB steam coal at Richard’s Bay. API2 and API4 are, respectively, the arithmetic mean of the CIF and FOB assessment published by specific reporting agencies from specified locations in named journals. Global Coal, headquartered in London, is an electronic platform that was created in 2001 by coal producers, end-users and others. Trading activities at the Global Coal electronic platform are compiled and published as the Newcastle (NEWC) Price Index, which is based on FOB steam coal prices at the NEWC terminal in Australia. It is an established benchmark for the Asia-Pacific steam coal market.

Nymex started trading coal futures in 2001, seeking to provide both the buyers as well as sellers with tools to hedge risks

against price volatility. A number of other coal futures markets such as London’s Intercontinental Exchange (ICE) and Global Coal, Germany’s European Energy Exchange (EEX) and the ASX have since been established. ICE Rotterdam futures and EEX ARA futures are settled against the API2 index in cash, while the ICE Richards Bay futures and EEX’s ICE Richard’s Bay futures are settled similarly against the API4 index. While Global Coal’s NEWC futures are settled against the NEWC index in cash, ASX’s FOB Newcastle futures are settled by physical delivery (ECS, 2007). A list of some of the coal price indices is given in Table 3.

Price competition in commodities markets is typically governed by supply and demand for most commodities. However, in the case of coal, factors that can potentially impact demand and supply dynamics such as the recent move to decarbonise energy pathways, or fluctuations in the cost of crude oil can also cause price movements, albeit indirectly. Different pricing mechanisms are also followed in Pacific and Atlantic markets. In cases of competitive CIF prices, inter-market deliveries become cost efficient. Distant suppliers become more competitive when the freight costs are lower. Any extra transport cost is normally borne by the suppliers. The coal market leaders today must consider all the prices offered by various competitors to retain market share, as coal is traded on a spot basis. The CIF prices at the destination port are important for any price-level formation, which in turn serves as the benchmark for long-term price negotiations. Carbon dioxide certificate trading may also in effect add to the price of coal when comparing the cost of other competing sources of energy and will be an important consideration in future. Long-term as well as spot transactions are now a common market phenomenon (Ritschel and Schiffer, 2007).

**Table 3.** Various coal price indices

NW Europe CIF (6000 kc NAR) – part of API2
Richards Bay FOB (6000 kc NAR) – part of API4
South African FOB (5500 kc NAR) – part of API3
Australian FOB (5500 kc NAR) – part of API5
Newcastle FOB (6000 kc NAR) – part of API6
South China CFR (5500 kc NAR) – part of API8
South China CFR (4900 kc, 6000 kc NAR) – produced with Xinhua
Qinhuangdao (domestic/export) FOB (5000, 5800 6000 kcal)
Indonesian FOB (6000 kc NAR)/FOB (5500 kc NAR)
Indonesian Sub-Bit FOB 4900 kc NAR, 4200/3800 kc GAR
Indian CFR (5500 kc NAR) East and West Coast – part of API12
India East Coast CFR and West Coast (5000 kcal/4200 kcal)
US East Coast and US Gulf High Sulfur FOB (6000 kcal)
Bolivar Colombian FOB (6000 kc NAR) – part of API10
Russian West Coast FOB (6000 kc NAR) East Coast (6700 kcal)
NEX (Newcastle Thermal Coal Export) Index

Note: kc GAR, kcal/kg gross as received; kc NAR, kcal/kg net as received  
Source: IHS Markit (2017)

Coal markets internationally are very dynamic, comprising a large number of suppliers actively supporting the power and manufacturing needs of countries, trading across markets, through a variety of quantities and instruments across a range of price indices for different regions. Despite these market dynamics, changes in demand for coal across various regions have resulted in severe volatility in coal prices over the past decade. However, the development of coal futures and derivatives is an indication that market mechanisms will significantly determine the future of coal. Figure 10 showcases the volatility in various coal prices between 2000 and 2016 as reported by the BP Statistical Review (BP, 2017).

The otherwise stable growth trajectory of coal has witnessed drastic changes in the past two decades fuelled by rapid growth after 2000 and a subsequent slowdown in 2014–2015 in the developing economies. With a growth in demand, coal prices

rose sharply as buyers purchased excessive amounts to counter any disruption in supply. The state of demand increased coal prices between 2003 and 2004, with some stabilisation in 2005. This was followed by yet another sharp increase in 2008 followed by a drastic decline in the wake of the global economic downturn of that time. Several reforms have been introduced by countries towards making coal prices (particularly domestic prices) more market-based (e.g. deregulation of coal prices in India and market-based pricing for coking coal in China) (ECS, 2010; ICIS, 2019). However, despite this, coal prices have remained extremely volatile due to a combination of factors, including a new political regime in the USA with the election of President Trump, and capacity expansion in south-east Asian countries. According to the IEA, coal prices are predicted to remain volatile and are likely to be affected heavily by economic rebalancing in policy priorities in major demand centres such as China, India, Korea and Japan (IEA, 2017a).

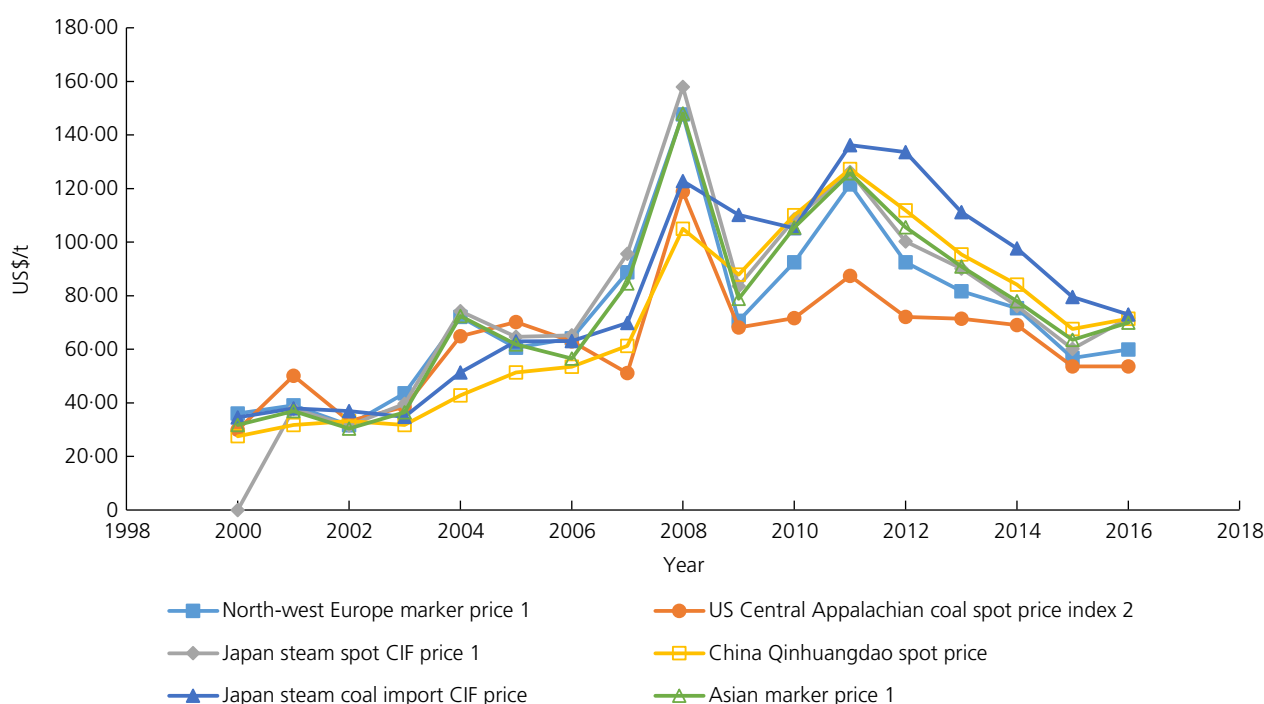


Figure 10. Coal prices 2000–2016 (source: BP (2017)). Notes:

- Prices marked 1 source: IHS north-west Europe (prices for 1990–2000 are the average of the monthly marker, 2001–2016 the average of weekly prices).
- IHS Japan prices basis = 6000 kcal/kg net as received (NAR) CIF.
- Asian prices are the average of the monthly marker.
- Chinese prices are the average monthly price for 2000–2005, weekly prices 2006–2016, 5500 kcal/kg NAR, including cost and freight (CFR).
- US Central Appalachian coal spot price index 2 source: Platts (prices are for CAPP 12 500 Btu (1 Btu = 0.25 kcal), 1.2 SO<sub>2</sub> coal, FOB).

A full-colour version of this figure can be found on the ICE Virtual Library ([www.icevirtuallibrary.com](http://www.icevirtuallibrary.com))

### 3.4 Coal and climate change

Scientists have reported that the concentration of carbon dioxide in the atmosphere was about 40% higher in 2016 than in the mid-1800s, with the energy sector representing the largest share of global anthropogenic greenhouse gas (GHG) emissions – approximately 68% (IPCC, 2013). The growing concerns over rapid climate change resulting from anthropogenic GHG emissions have shaped much of the public and political debate for a little over 25 years. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC, 2018) committed parties to an international treaty to combat climate change with the goal of limiting global average temperature increases putting in place a range of adaptation and mitigation strategies (Figure 11).

However, no binding GHG emission reduction commitments were set on any individual country at the time. These parties have met annually since 1995 at the Conference of Parties (COP) to evaluate the progress of efforts in dealing with climate change. Several milestones in climate negotiation have since been passed such as the Kyoto Protocol in 1997, the Copenhagen Accord of 2009 and more recently the 2015 Paris Agreement, which marks the latest step in the evolution of climate change and energy policies across the world (UNFCCC, 2016). These agreements are influential in maintaining significant pressure on the polluting fossil-fuels sector and seek to alter significantly the existing energy systems towards cleaner, more efficient and sustainable activity.

Within the energy sector, fossil fuel combustion dominates the total GHG emissions, of which 44% stem from coal (Schernikau, 2017; 45% as per the IEA). Ecologically, coal is one of the most polluting fuels; its combustion generates large amounts of carbon dioxide, oxides of sulfur and nitrogen ( $\text{SO}_x$  and  $\text{NO}_x$ ), particulate matter such as fly ash and dust, and

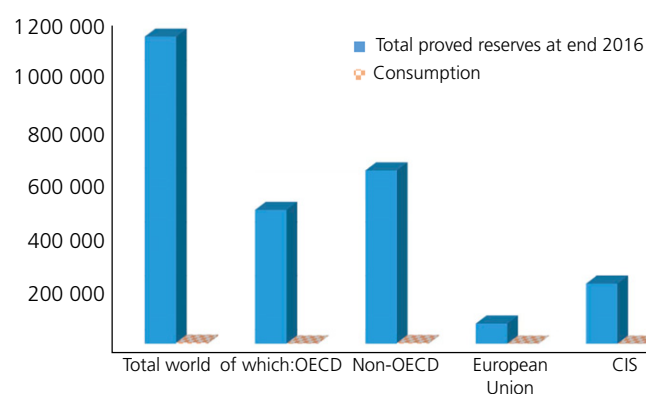
trace elements such as mercury (Aslanian, 1991; WCI, 2005: p. 29). The continued use of coal at scale by way of the approach in use today is therefore regarded as a major threat to the future climate and global ecology.

In recognition of the need to reduce GHG emissions, substantial funding has been allocated by governments all across the globe for research, development and adoption of a wide range of technologies reducing coal-generated-emissions and bringing improved energy efficiency. Clean coal technologies aim to improve the environmental performance of coal and address a cascading set of environmental challenges. The goal is to eliminate the emission of particulate matter and other pollutants such as the oxides of sulfur and nitrogen and reducing carbon dioxide emissions per unit of electricity generated by increasing thermal efficiency (WCI, 2007b).

While the IEA, on the basis of technology type, identifies five groups of ‘clean coal’ technologies: coal upgrading, efficiency improvements at existing power plants, advanced technologies, near-zero emission technologies and carbon dioxide transport and storage technologies (IEA, 2009), the World Coal Institute categorises them into coal preparation, technologies for reducing emissions of pollutants, efficient combustion technologies and carbon dioxide capture, utilisation and storage (CCUS) technologies (WCI, 2005). Table 3 presents an overview of some of the clean coal technology options and their current status. The Global CCS Institute reports 43 large-scale carbon capture and storage (CCS) projects – 18 in commercial operation, five under construction and 20 in various stages of development (GCCSI, 2018). (More detailed information on a range of CCS projects is available at the Global CCS Institute website; also IEA (2009); Northam *et al.* (2016)) (Table 4).

In 2015, the top anthropogenic carbon dioxide emitters were China (26%), emitting primarily from coal; the USA (16%), emitting from oil, gas and coal; India (6%), emitting primarily from coal; Russia (5%), emitting primarily from gas; and Japan (4%), emitting from oil, coal and gas (Schernikau, 2017). Today a trend away from the use of coal is indeed seen in some, but by no means all, wealthy developed countries (BP, 2016; IEA, 2017a). Developing countries, on the other hand, have registered a huge increase in their use of coal for electricity generation over the past 25 years. It is worth highlighting that Asia houses 60% of the global population, half of which lives in China and India, the two most populous countries of the world (Baruya, 2016).

While China is working towards developing lower-emission coal-fired power plants, in addition to developing other cleaner sources of energy, other developing countries in Asia continue



**Figure 11.** Total proven reserves against consumption in 2016 in Mt (author's interpretation, source: BP (2016))



Table 4. Overview of 'clean coal' technologies

Technology	Description	Status
<b>Coal preparation</b>		
Coal beneficiation (or coal washing)	The process includes treatment of run-of-mine (ROM) coal (coal straight from ground) to ensure an improved quality suited to its specific end-uses. The process may include washing, crushing and separating into various size fractions using tank or froth flotation. The process increases the heating value and quality of coal, and the overall efficiency of coal-fired power plants.	Widely developed and used both in developed and developing countries. Can be used to bring about up to 5% reduction in carbon dioxide emissions.
<b>Particulate emission and pollutant reduction technologies</b>		
Activated carbon injection (ACI)	Powdered activated carbon is injected from a storage silo into the flue gas ductwork of a cement kiln or coal-fired power plant. Pollutants like mercury are absorbed on particulate matter before being removed in particulate control equipment.	ACI for coal-fired power plants was first tested and introduced in the early 1990s. With wider adoption of regulations like the large combustion plant best available techniques reference document (LCP BREF) and stricter limits for particulate emission, ACI technologies are likely to be widely adopted in the EU, China, India, South Africa and other coal-burning countries.
Electrostatic precipitators (ESPs) and fabric filters	ESPs and fabric filters can be used to control particulates from coal combustion. ESPs use electric field to create a charge between collecting plates, whereas tightly woven fabric similar to a sieve is used in fabric filters to collect particles from the flue gas.	With a potential to remove over 99.5% of particulate emissions, this equipment is widely used in developed as well as developing countries to improve the environmental performance of coal-fired power stations.
Hot gas filtration systems	These operate at high temperatures (500–1000°C) and pressures (1–2 MPa).	Technologies such as cyclones, ceramic barrier filters, high-temperature fabric filters, granular-bed filters and so on are being developed and carefully considered for enhanced commercial application.
Flue gas desulfurisation (FGD)	Sulfur emission from the combustion of coal can be removed by FGD technologies. The FGD technologies can be classified as: wet scrubbers; spray dry scrubbers; sorbent injection processes; dry scrubbers; regenerable scrubbers and combined sulfur and nitrogen oxides removal processes. An alkaline sorbent slurry like lime or limestone reacts with sulfur dioxide in the flue gases forming gypsum in flue gas cleaning plant or scrubbing vessel.	With proven removal efficiency of 90–99%, wet particle scrubbers are used additionally to capture fly ash. This technology is widely used in the US.
Selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR)	These technologies can be used to treat emissions of oxides of nitrogen (NO <sub>x</sub> ) from coal combustion in the exhaust gas stream and have been proven to reduce nitrogen oxides emissions by around 80–90%. SCR systems use ammonia vapour as a reducing agent, which is injected over the stream of flue gas and passed over a catalyst. SCR systems operate between 300 and 400°C, much lower than those of 870–1200°C used by SNCR systems, thereby requiring a catalyst to speed up the chemical reactions.	

(continued on next page)



Table 4. Continued

Technology	Description	Status
<b>Efficient combustion and reducing carbon dioxide emissions technologies</b>		
Pulverised coal combustion (PCC)	In power stations using PCC, coal is first pulverised and blown at high temperatures for combustion in furnaces producing steam which is used to drive turbines and generator.	Improvements in thermal efficiency of coal-fired power stations significantly increase the energy being produced from the fuel. Currently, the global average thermal efficiency of coal-fired power stations is around 30%, with OECD countries' average ranking higher than those in developing countries. However, with new supercritical and ultra-supercritical technologies can achieve efficiency levels between 43 and 50%.
Fluidised-bed combustion (FBC)	In FBC, gas is fed through a bed in the reactor where coal is burned, improving its combustion, heat transfer and aiding the recovery of waste products. FBC reactors operate at a lower temperature than the PCC systems due to improved heat exchange efficiencies and better mixing in FBC systems. The gas streams can be subjected to high pressures within the bed and used to drive gas turbines producing electricity. Several kinds of FBC technologies like bubbling fluidised-bed combustion, circulating fluidised-bed combustion, pressurised fluidised-bed combustion, pressurised circulating fluidised-bed combustion exist and are being further developed.	IGCC systems can operate at close to 50% efficiency, while simultaneously removing 95–99% of nitrogen and sulfur oxides emissions. World Resource Institute reports around 400 supercritical plants and 160 IGCC plants operating across the world.
Pressurised pulverised coal cycle (PPCC)	In PPCC technologies combustion of a finely pulverised cloud of coal generates high-temperature and high-pressure steam, which is used in turbine generators to produce electricity.	
Integrated gasification combined cycle (IGCC)	In IGCC systems, coal is reacted with oxygen and steam to produce syngas (see Section 2.2 for more information), which in turn is burnt in a gas turbine to generate electricity and produce steam for the steam power cycle.	
Supercritical and ultra-supercritical technology	These operate at higher steam temperature and pressures than conventional plants. At such high temperature and pressures, the single-phase fluid is passed through boilers and used in supercritical cycles, bringing about increased efficiencies of over 50%.	
Carbon dioxide capture, utilisation and storage (CCUS)	CCUS technologies include methods and technologies to remove carbon dioxide from the flue gas and recycling and utilising it the most efficient and safe way possible. Sorbents that can bind with the carbon dioxide in the flue gas are used to capture carbon. The captured carbon dioxide is then used in food processing or the chemical industry, or for oil extraction or remediation of alkaline industrial wastes. However, given the limited demand for carbon dioxide, various viable storage options for carbon dioxide are being developed. Some of the proposed options include injecting carbon dioxide in geologic formations and oceans, and growing trees to enable biological fixation of carbon dioxide by way of photosynthesis.	A number of CCUS projects are being test-run around the world. There is significant effort underway in the UK through the government's Clean Growth Strategy to support the development of CCUS in the UK and internationally. However, CCUS technologies are currently expensive and cost reductions are needed for any further successful deployment and their adoption in developing countries.

Source: WCI (2007b), IEA (2008), Northam *et al.* (2016)

to rely heavily on cheaper and traditional coal-fired power generation. Even if one were to be optimistic and pointed to evidence of the patchy emergence of reduced interest in the use of coal for electricity generation, it is important to recognise the major role played by coal in steel making and other heavy industrial processes (Katzner *et al.*, 2007; see earlier sections for

details on industrial uses of coal). In such areas the impact of climate concerns on coal usage would appear, thus far, to be even weaker than in the electricity sector.

Furthermore, with a predicted increase in population and a strong desire for improvements in living standards in the

emerging economies, the emissions from many developing countries are set to increase significantly. For example, coal use in India and Association of Southeast Asian Nations (ASEAN) countries in the near future, according to various reports, including IEA's *Coal 2017* (IEA, 2017a), is predicted to grow significantly.

Noting that in some territories a continued role of coal appears to be inevitable, and noting the need to reduce environmental harm, it seems prudent to advance research and development in clean coal technologies in the short-to-medium term. A wider adoption and at-scale integration of clean coal technologies present the prospect of a global clean coal technology market, which was valued at US\$5970 million in 2017 and is predicted to grow at a compound annual growth rate of 2.1% during 2018–2025 reaching US\$7050 million by the end of 2025 (QYRG, 2018).

With the deemed role played by coal as a contributor to the climate problem since the early 1990s exacerbated by a nearly two-and-half-fold increase in global population and related pollution issues over the preceding three decades, disappointment must be expressed over the slow pace at which steps have been taken to reduce the output of harmful gases from the use of coal and other fossil fuels for power generation. There is hope that the anticipated future global coal utilisation might be accompanied by improved efficiency through pre-treatment and emissions clean-up, including carbon dioxide. As things stand, however, a low-emissions future for coal remains some way away and this must be seen as a major problem requiring effort over the next decade and beyond.

### 3.5 Coal in the energy mix and outlook 2022

The importance of coal in the energy mix can be assessed simply by the fact that about one-third of all energy and 40% of the electricity generation globally is based on coal (IEA, 2017a). Coal is also crucial to heavy industries like steel and iron. Of the total electricity access provided in the last two decades, around 45% was powered by coal (WCA, 2017). IEA (2017) predicts the share of coal in the energy mix in 2022 to remain at 26%, dropping 1% from 2017 levels. With reference to Figure 11, world proven coal reserves in 2016 were estimated at 1 139 331 Mt, sufficient to meet 153 years of global production (compared to 61 years for gas and 54 years for oil), according to BP (2016). Despite certain advancements in renewable capacity and falling renewable prices, coal remains competitive for electricity generation in India, China and south-east Asia. The electricity produced from coal in these countries costs significantly less than that from most renewable sources, and will continue to play a key position in the global energy mix, looking ahead (IEA, 2017b).

On the whole, according to the IEA predictions, and as previously stated in preceding sections, the share of coal in the global energy mix in the coming decade will remain prominent (perhaps declining only by 1% between 2016 and 2022, from 27 to 26%). Most of the growth is likely to occur in India and ASEAN countries. With declining demand in Europe and Canada and uncertainties in USA and China, IEA forecasts coal demand to reach 5530 Mtce in 2022. Despite the global concern for climate change and a stated wider consensus on action following the 2015 Paris climate agreement, global coal-fired power generation is forecast to increase by 1.2% per year, with the share of coal in the power mix falling to 36% due to rapidly falling gas prices and possibly more output from renewable projects. Countries such as Pakistan, Bangladesh and Indonesia are predicted to increase their consumption of coal significantly between 2016 and 2022.

China's policy and economic restructuring is aimed at 'making its skies blue', despite a projected increase in coal-power generation. Coal is expected to supply over 55% of China's energy demand in 2022. Meanwhile, with Indian mines running at less than 60% of capacity, which is predicted to improve with an ongoing structural reform in mining practices and increasing pressures from electrification, coal-fired generation in India is forecast to increase at 4% per year through 2022. Fast-paced economic growth will see a steep increase in the consumption of coking coal, driving a 5% increase in its import per year through 2022 in the country (IEA, 2017a). Many south-east Asian countries have already emerged to provide the fastest growing demand hub for energy, recording an increase of over 150% in energy demand over the past 25 years, and predicted to reach 1070 Mtce by 2040. During this period, electricity demand nearing 1104 TWh is forecast, half of which is forecast to come from coal (WCA, 2005). It is noteworthy to mention that 120 million people in ASEAN countries currently live without access to electricity according to WCA 2016 estimates.

Coal, in the USA, is no longer in total retreat, with the introduction of new measures and reforms by the Federal Government and announcements by the recent Trump administration to deliver '1000 years of clean coal' (DiChristopher, 2016). Coal production in the USA is forecast to be around 510 Mtce in 2022, while demand is likely to decline at an average of 1% per year through 2022. The USA will remain a swing supplier into both Atlantic and Pacific markets, and according to the forecasts, will exhibit the highest uncertainties of all coal exporters. Australia, Indonesia, Russia, Colombia and South Africa are predicted to be the top exporters. The USA is active in seeking a reportedly cleaner solution in coal production, and close to operating completion of a new plant in Wyoming using their Powder River Basin deposits (CCTI, 2018). The issue is of interest to Asia-based coal users.

The future of coal in the twenty-first century will be significant both in driving growth in developing countries and in thereby potentially contributing to climate damage. Coal will also cause significant movements in energy geopolitics by changing established patterns of demand and supply and trade flows. Future trading instruments will play a key role maturing coal markets. While coal provides a secure and affordable supply of energy, more political will and significantly higher investments are required to support a successful transition towards lower-emission coal technology if coal is to play a part in the journey to decarbonisation. Financial and technological investments towards the deployment of CCUS will be needed if there is to be a long-term future of coal, although to date cost implications have caused hesitation in pursuing this approach.

Policy priorities pursued by the biggest demand centres will, more than anything, determine growth, stagnation or decline in demand for coal or more interest in its conversion to gas or liquid. In recent years, much concern has been raised regarding the growing coal consumption and usage in China and the associated GHG emissions. Arguably, over the past two decades, China has built prosperity on the basis of coal in a way that took Europe and America almost 200 years. However, at this point in time there is evidence that China may finally be deeply and sincerely acting to address the harmful environmental consequences of untreated coal combustion.

India, on the other hand, is less often presented as the face of the global carbon dioxide problem with continued assurances from the government, including the recent indication by Prime Minister Modi that the country will go ‘above and beyond’ the Paris agreement. India’s sincere efforts to provide ‘Universal Electrification’ and promote ‘Make in India’ is driving strong growth in unabated coal combustion. Despite recognising the potential of climate threat globally and committing to take concerted action to transit to a cleaner energy pathway, India has not yet chosen to follow China towards beneficial technical innovation, due to a range of conflicting political realities and priorities. Unfortunately, it cannot be said with clarity whether India in 2050 will be in a better place than it is now. There is a risk that if India does not act soon and start embracing clean coal technologies more seriously and move more aggressively away from fossil fuel use, it will assume the status of the world’s biggest polluter.

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